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SIMULATION MODEL OF A SINGLE-STAGE LITHIUM BROMIDE - WATER ABSORPTION COOLING UNIT

by David Miao

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SUMMARY

The performance and load capability of a given LiBr-H₂O absorption chiller operating with a hot-water heat source depends on six quantities: the inlet temperatures and flow rates of the hot-water source, the cooling-tower water, and the return chiller water. Based on this, a computer model for a single-stage absorption cooling machine has been developed which does not require data relative to the interior characteristics of the machine (heat-transfer rates and surfaces). The model considers both heat-transfer and thermodynamic processes. It consists of two algorithms, one for the design, or reference conditions, and the other for the off-design analysis. It is constructed from the steady-state equations but may also be used for the transient analysis of a cooling system.

The program can be used in an independent mode or as a subroutine, as for example, with TRNSY'S, for the analysis of a cooling system. For a given size of machine the model can be used to predict off-design cooling-system performance, the only input requirements being a set of reference or rated conditions for the machine.

INTRODUCTION

The LiBr-H₂O absorption liquid chiller has been used in the refrigeration and air-conditioning industry for some time. One of the primary reasons for using this type of machine is that steam or hot water, whichever is available, can be directly used as an energy source to power the machine. This characteristic is particularly attractive for solar-cooling applications.

In a typical solar-cooling application, water heated through the passages of a bank of solar energy collectors is used to power an absorption machine to provide chilled water which in turn is used to air condition the building.

Typically an absorption chiller is designed to handle the maximum expected load of the building. The design point thus represents a set of fixed operating conditions. However, the actual load varies with building heat-transfer characteristics as well as local weather conditions. The design load may seldom be experienced. Since the chilled-water temperature is likely to increase with decreasing heat load (part-load operation), the chiller may be incapable of dehumidification.

An approach is, prior to machine selection, to simulate various loading conditions through a computer model of the machine. The typical models available today are either empirical (ref. 1), or based upon a thermodynamic approach. The former generally represents a specific machine, and therefore its usefulness is limited; the latter is useful for providing a set of design conditions to the machine manufacturer to determine the size of an absorption machine.

A thermodynamic approach can be used for simulating various operating conditions but such a model does not recognize limitations of the heat-transfer processes. A better approach is to take both heat-transfer and thermodynamic processes into consideration. Furthermore, if an existing machine is selected for a specific job, the heat-transfer surfaces in the machine are fixed but often not known, and therefore it will be difficult to determine the capability of the machine over a range of operating conditions. The only known inputs are three sets of inlet flows and temperatures to the machine: namely, the flow rates and corresponding temperatures of the return chilled water, the cooling water, and the incoming hot water. The unknowns required to be established are the corresponding outlet temperatures of the three flow streams. A computer model for handling this type of problem is not generally available. The purpose of this report is to document a method for modeling the system.

THERMODYNAMIC CYCLE

The thermodynamic cycle of the absorption machine is well known (refs. 2 to 4). Figure 1 represents a typical arrangement of a single-stage machine. The machine basically consists of five heat exchangers called a generator, a condenser, an evaporator, an absorber, and a solution heat exchanger. For a heat load imposed on the evaporator E, the LiBr-H₂O strong solution is pumped through the solution heat exchanger X to the generator G. Heat energy is added in the generator G to drive out the refrigerant (in this case, water is the refrigerant). The remaining solution is called the weak solution. A portion of the weak solution is forced through the solution exchanger X and a pressure reducing valve V1 back to the absorber A for the next cycle. To make a strong solution in the absorber A, the refrigerant leaving the generator G must also be brought back to the absorber through a condenser-evaporator path. In the process, the refrigerant is first condensed by removing its latent heat in the condenser C; then in passing

through an expansion valve V2, the pressure and the temperature of the refrigerant are reduced. The refrigerant is evaporated due to heat load addition in the evaporator E. The refrigerant vapor is then brought to the absorber A to be absorbed. When the heat of absorption is removed, the strong solution is restored and the new cycle begins.

Most commercial machines are built on this basis. To simulate machine performance, a thermodynamic cycle analysis is used to perform heat balance calculations in order to establish heat input and cooling requirement for a refrigeration load. Heat inputs and outputs of the machine are marked in figure 1. The solid arrow lines indicate the direction of heat flow as well as fluid flow interior to the machine while the dashed lines indicate heat or fluid flowing into or out of the machine. Figure 1 is used to construct the thermodynamic portion of the machine model.

To perform such calculations, thermodynamic properties of the water and the LiBr-H₂O solution are also needed. Such information is readily found in reference 2 (the formulas used may be found in appendix A).

HEAT-TRANSFER CONSIDERATIONS

The thermodynamic analysis determines the cycle temperatures and the required heat flows for the five heat exchangers in the absorption machine as shown in figure 1. For a given refrigeration load, the heat exchangers must be designed to satisfy the aforementioned requirements. Once the heat exchangers are designed, the heat-transfer surfaces are fixed and heat transfer is limited by the surfaces provided in the machine. Therefore, for all operating loads the performance of the machine is determined from the actual heat-transfer surface areas.

In terms of heat-transfer processes on the LiBr-H₂O solution side, the heat exchangers may be classified into two types: The solution heat exchanger X (fig. 1) which deals strictly with sensible heat transfer is one type - and the other four: G, A, E, and C (fig. 1) which involve latent heat are another type. Heat exchangers G and A deal also with the heat of absorption, but since their heat-transfer coefficients are high and their temperature profiles are fairly constant, the heat-transfer analysis is treated in the same manner as those of exchangers E and C. The following equations (ref. 5) are used for these four exchangers:

$$EFFN = \frac{T_1 - T_2}{T_1 - T} \quad (1)$$

where

EFFN temperature effectiveness of heat exchanger

T_1 inlet temperature of heating or cooling medium

T_2 outlet temperature of heating or cooling medium

T temperature of LiBr-H₂O solution of refrigerant (water) undergoing evaporation, absorption, or condensation process

To relate the temperature field to the heat transfer, EFFN is rewritten as

$$\text{EFFN} = 1 - e^{-UA/GC_p} \quad (2)$$

where

U overall heat-transfer coefficient of heat exchanger

A total heat-transfer surface

G flow rate of heating or cooling medium

C_p heat capacity of medium

Equations (1) and (2) are used to solve for the required outlet temperatures T_2 's of the four heat exchangers involving external fluid flows. Ideally, if all temperatures and flow rates are given at the design load, equations (1) and (2) should resolve four UA's for that machine.

To simulate various heat loads other than the design, the corresponding UA's must be calculated from additional equations so that equations (1) and (2) can be used to obtain the various outlet temperatures T_2 's. However, the information about the heat-transfer surface is usually not available and the UA terms are inseparable. Therefore, the next equations are derived on the UA term basis.

Heat exchangers of this kind are typical shell-tube type. The cooling or heating medium is usually on the tube side, and the refrigerant (water) or LiBr-H₂O solution is on the shell side. The heat-transfer process is governed by the mechanism of the fluid flow on both sides and the tube wall thermal resistance. By definition U is written as

$$\frac{1}{U} = \frac{1}{h_w} + \frac{1}{h} + R_t + F \quad (3a)$$

where

h_w tube-side coefficient due to forced convection

h shell-side coefficient

R_t tube wall resistance

F sum of fouling factors on both sides

The R_t term in formula (3a) is a function of the tube wall thickness and the material of construction. Typically, its magnitude is very small because of low pressure operation and the use of high conductivity copper based tube material.

The design or selected fouling factor F (ref. 6) is also rather small. The true fouling factor varies with water conditioning and plant operation and cannot be established without test data. Both R_t and F may be considered constant throughout machine operation.

The h term, due to latent heat transfer, is very high for a good cost effective heat exchanger design. The h value for boiling water or steam condensation may be on the order of two to six times the forced convection coefficient h_w (ref. 7). Therefore, it is not a strong factor on the overall heat-transfer coefficient U , which may be conveniently written as

$$U = h_w \left(\frac{1}{1 + h_w R} \right) \quad (3b)$$

where R is the sum of the resistances $(1/h) + R_t + F$.

Equation (3b) implies that U can be found if h_w is known.

To find h_w on the tube side, the following forced convection formula for turbulent flow (ref. 7) is used:

$$\frac{h_w D}{k} = (0.23) \left(\frac{DG}{\mu A_c} \right)^{0.8} \left(\frac{C_p \mu}{K} \right)^{0.4} \quad (4a)$$

where

D inside diameter of tube

K thermal conductivity

μ viscosity

A_c flow area

Equation (4a) indicates that the change of h_w is sensitive to the changes of the flow rate G (eight-tenth power function) but less dependent on the heat transport properties. Furthermore the fluid temperature variations for an absorption machine are rather small, especially in a solar application; thus these temperature dependent properties remain practically constant. Therefore equation (4a) may be rewritten as

$$h_w \propto G^{0.8}$$

Since proportionality can be established, h_w may be written as follows in terms of a reference condition with the subscript 0:

$$h_w = \left(\frac{G}{G_0} \right)^{0.8} h_{w0} \quad (4b)$$

$$U_0 = h_{w0} \left(\frac{1}{1 + h_{w0} R_0} \right) \quad (3)$$

By combining equations (3b), (3c), and (4b) and solving for U , we obtain

$$U = \left(\frac{G}{G_0} \right)^{0.8} \left(\frac{1 + h_{w0} R_0}{1 + h_w R} \right) U_0 \quad (3d)$$

As long as the term $h_w R$ is not substantially different from $h_{w0} R_0$, the factor $(1 + h_{w0} R_0)/(1 + h_w R)$ is approaching unity. If this term is assumed to be one, the expected error in U is 5 to 10 percent. Under the worst conditions, the error may be as high as 20 percent. Therefore, equation (3d) may be reduced to

$$U = \left(\frac{G}{G_0} \right)^{0.8} U_0$$

or

$$UA = \left(\frac{G}{G_0} \right)^{0.8} (UA)_0 \quad (3e)$$

Equation (3e) implies that, if a reference condition is known, the UA term at other conditions can be found given the right flow proportions. To find a reference UA , equations (1) and (2) must be used and flow rates are referred to the reference condition. Using actual measured values in the aforementioned formulas instead of the machine design values for the reference point is desirable wherever possible.

The second type of heat exchanger in the absorption machine is a liquid to liquid exchanger (exchanger X in fig. 1). This exchanger is placed in the absorption circuit to improve cycle efficiency. It is also typical of a shell-tube type with a true counterflow arrangement for better heat recovery. The strong solution (rich with water refrigerant)

is pumped through the tubes and the weak solution flows across the tube bundles, with flow deflecting baffles. As was pointed out previously, the heat-transfer rate is a strong function of the flow rate. The strong solution flow rate is greater than that of the weak one. To achieve a high heat-transfer coefficient on the tube side, it is natural for the heat exchanger designer to place the strong solution in the tubes. In addition, the better heat transport properties of the strong solution (more water content) aid in achieving a high coefficient. The lower shell-side coefficient of the weak solution can be improved by using spaced baffles.

Equation (4a) is used to calculate the tube-side coefficient. Equation (4b) is also applicable if the heat transport properties remain practically constant.

As indicated previously, equation (4a) or (4b) is applicable for turbulent flow. For a true counterflow type of heat exchanger, or single-tube pass arrangement, the velocity in the tubes may be reduced under some part load operation. It is possible the flow pattern may shift into the laminar region. Then equation (4a) or (4b) would not be applicable, and the formula for laminar flow (ref. 7) would have to be used.

Since this report is concerned with the simulation of a previously designed machine without knowing the interior arrangement of the heat-transfer surface areas, the laminar formula, even if it is available, is probably not useful for model construction. However, it is reasonable to assume that the turbulent flow formula is used for calculating the tube-side heat-transfer coefficient. In these machines, the heat exchanger with longer tube lengths (thus small flow area and high velocity in the tube) is commonly seen in commercial machines.

The formula for the shell-side coefficient (ref. 7) may be written as follows because the heat transport properties remain practically constant:

$$\frac{h_{gw} D_e}{K} = 0.33 \left(\frac{D_e G_w}{\mu A_{cross}} \right)^{0.6} \left(\frac{\mu C_p}{K} \right)^{0.3}$$

or

$$h_{gw} \propto G_w^{0.6} \quad (5)$$

where

D_e equivalent diameter

h_{gw} coefficient of weak solution flow rate

A_{cross} flow passage area measured along shell inside diameter

Unlike the tube-side formula, equation (5) is not restricted by the turbulent flow. The shell-side coefficient can be increased by means of closer baffle spacings.

Therefore, it is reasonable to assume that the weak solution with less flow rate is on the shell side.

The relation between the overall heat transfer and the individual coefficients is the same as that of equation (3a). In this case the controlling resistance is on the tube side because of the single tube pass arrangement. The magnitude may be on the order of the shell-side coefficient. Since heat-transfer coefficients on both sides are poor, the magnitude of $(1/h_w) + (1/h)$ in equation (3a) is much larger than that of R_t and F (perhaps 10 times larger); therefore, R_t and F are neglected and equation (3a) may be re-written as

$$\frac{1}{U_x} = \frac{1}{h_{gs}} + \frac{1}{h_{gw}} \quad (6a)$$

where

x refers to solution exchanger

gs refers to strong solution

gw refers to weak solution

For a referenced condition, equation (6a) becomes

$$\frac{1}{U_{x0}} = \frac{1}{h_{gs0}} + \frac{1}{h_{gw0}} \quad (6b)$$

Once again for a given machine, where the interior construction of the machine is not known, equation (6b) cannot be solved without making assumptions. If h_{gs0} and h_{gw0} are assumed equal, equation (6b) becomes

$$h_{gs0} = h_{gw0} = 2U_{x0} \quad (7)$$

By combining equations (7) and (4a) or (5), h_{gs} and h_{gw} can be obtained for other simulated conditions; specifically

$$h_{gs} = \left(\frac{G_s}{G_{s0}} \right)^{0.8} h_{gs0} = \left(\frac{G_s}{G_{s0}} \right)^{0.8} (2U_0) \quad (8)$$

$$h_{gw} = \left(\frac{G_w}{G_{w0}} \right)^{0.6} h_{gw0} = \left(\frac{G_w}{G_{w0}} \right)^{0.6} (2U_0) \quad (9)$$

Then substituting equations (8) and (9) into equation (6a) and rearranging the terms yield

$$U_x = (2U_{x0}) \left[\frac{1}{\left(\frac{G_{s0}}{G_s}\right)^{0.8} + \left(\frac{G_{w0}}{G_w}\right)^{0.6}} \right] \quad (10)$$

Since the heat-transfer surface area is fixed, equation (10) may be written as

$$(UA)_x = 2(UA)_{x0} \left[\frac{1}{\left(\frac{G_{s0}}{G_s}\right)^{0.8} + \left(\frac{G_{w0}}{G_w}\right)^{0.6}} \right] \quad (11a)$$

Equation (11a) again shows that the overall heat-transfer rate at any other condition can be established through a known reference condition (design or test). Equations (8) and (9) can also be extended to include the property corrections if better accuracy is desired. The heat transport properties except thermal conductivity may be found in reference 3. For thermal conductivity values for various LiBr-H₂O solutions, a fraction of water conductivity proportional to water concentration are suggested. In general these effects on heat-transfer coefficients are small and will not be taken into consideration at this time.

The aforementioned equations were derived on the assumption that $h_{gs0} = h_{gw0}$; the assumption appears valid because (1) the fluid properties on both shell and tube sides are similar and (2) the flow rates are not substantially different within the operating range of the solution concentration. However, if h_{gs0} is substantially different from h_{gw0} , equation (11a) may be generalized as

$$(UA)_x = (F1)(UA)_{x0} \left[\frac{1}{\left(\frac{G_{s0}}{G_s}\right)^{0.8} + (F2) \left(\frac{G_{w0}}{G_w}\right)^{0.6}} \right] \quad (11b)$$

where, for example,

$$\begin{aligned} h_{gs0} &= h_{gw0} & F1 &= 2 \text{ and } F2 = 1 \\ h_{gs0} &\ll h_{gw0} & F1 &= 1 \text{ and } F2 = 0 \\ h_{gs0} &= 1.5h_{w0} & F1 &= 2.5 \text{ and } F2 = 2/3 \end{aligned}$$

Equation (11b) may be useful to experimentally determine the actual values of $F1$ and $F2$ for use in the program for a given machine.

Equation (11a) or (11b) can be solved if $(UA)_{x0}$ is known or may be found from a given set of the design temperatures. The effectiveness is given in terms of the temperatures (refs. 1 and 4) as

$$EFFNX = \frac{T_g - T_5}{T_g - T_a} \quad (12)$$

where

T_g temperature of generator

T_5 outlet temperature of weak solution

T_a temperature of absorber

In general the exchanger is designed with the effectiveness $EFFNX_0 = 0.7$ to 0.8 . If T_5 in equation (12) for the design load is not known, the relation between $EFFNX_0$ and T_{50} may be established by heat balance (ref. 1).

When $EFFNX_0$ is found together with flow rates G_{s0} and G_{w0} and the solution heat capacities C_{s0} and C_{w0} , then $(UA)_{x0}$ is calculated from the following equation:

$$EFFNX = \frac{1 - e^{-NTU_x [1 - (C_{min}/C_{max})]}}{1 - \left(\frac{C_{min}}{C_{max}}\right) e^{-NTU_x [1 - (C_{min}/C_{max})]}} \quad (13)$$

where

$NTU_x = (UA)_x / C_{min}$

$C_{min} = G_w C_w$

$C_{max} = G_s C_s$

C_w heat capacity of weak solution

C_s heat capacity of strong solution

The subscript 0 used previously has been deliberately omitted in equations (12) and (13) for the purpose of generalization. Then $C_{\min} = (G_w C_w)$ and $C_{\max} = (G_s C_s)$ because $G_w < G_s$ and $C_w < C_s$ for LiBr-H₂O absorption machine. The $(UA)_{x0}$ is solved implicitly in equation (13).

OTHER CONSIDERATIONS

The equations derived in the previous section together with the thermodynamic equations discussed in the section THERMODYNAMIC CYCLE are the working formulas for the five heat exchangers to be used in the construction of the simulation model. In addition to these formulas, heat losses, pump capacity, operating range of the solution concentrations, and operating temperature limits should be included. Unfortunately machine construction does vary with the design approach of different manufacturers, and the construction information is usually not available. It is difficult to generalize all the limitations to be accommodated by the model. Nevertheless, some of the important considerations that should be taken into account follow.

Heat Losses

The heat losses vary with the specific design and the ambient environment in which the machine is installed. Heat may leak out of or into the machine, and between the partition shells separating the heat exchangers in the machine. The result is that additional heat supply is required to accommodate these losses. To account for these losses, a simplistic approach is to add a fixed percentage to the heat supply. A few percent may be sufficient for the type machine considered herein. The thermodynamic equations (appendix A) may be modified as follows:

$$Q_G = (G_w H_5 - G_s H_1 + G_R H_7)(FGQ) \quad (14)$$

$$Q_C = G_R(H_7 - H_8) \left[1 + \left(\frac{Q_G}{Q_G + Q_E} \right) (1 - F_{QG}) \right] \quad (15)$$

$$Q_A = (G_w H_5 - G_s H_1 + G_R H_{10}) \left[1 + \left(\frac{Q_G}{Q_G + Q_E} \right) (1 - F_{QG}) \right] \quad (16)$$

where

F_{QG} multiplication factor

$F_{QG} = 1$ (no heat loss considered)

$F_{QG} = 1.02$ (equivalent 2 percent loss)

Solution Pump Capacity

Normally the pump capacity is chosen to meet the design load. For part load operation, the required flow rate may or may not exceed the maximum capacity. For a particular load demand, if heat source temperature is low and/or the cooling water temperature is high, the machine, based on the thermodynamic cycle analysis, tends to demand more solution flow. Since the flow control is not known and varies somewhat with different machines, it is assumed that the solution flow rate cannot exceed the capacity of the design point.

Concentration of the LiBr-H₂O Solution

For an absorption process to exist in operation, there are limits on the solution concentrations. If the concentration is too rich, crystallization will occur. If the concentration is too lean, no absorption process will occur. Reference 2 suggested that the concentrations should be kept within 0.5 to 0.65 range. For this model a range from 0.4 to 0.68 has been used.

Temperatures and Temperature Differences

The temperature limitations, like the solution concentrations, are set for the operable absorption process. Usually these are the outlet temperatures of the external fluids in heat exchanger G, C, A, and E (fig. 1). The limits of these temperatures have been placed in the program (see appendix B).

In addition to the temperature limits, the temperature difference across the heat exchanger surfaces are also limited by the heat-transfer processes. In general the temperature differences between the two heat exchange mediums at outlet condition will be used for setting the limits (see appendix B).

When the aforementioned limits and the concentration limits are properly set, the solution heat exchanger temperature as well as the pressure limits may be neglected.

MODELING ALGORITHM

With the necessary equations and the limiting conditions established, the next step is to formulate an algorithm for computer operation. The desired solution for a given set of inputs is the one that achieves the lowest possible outlet temperature of the chilled water. The heat balance is not only required to satisfy the thermodynamic analysis but also simultaneously satisfy the heat exchanger equations.

The model consists of two different algorithms. One part is used to solve for the reference or design conditions. Another part is used to solve for the off-design condition based on the established reference condition. The second part is simply to perform an internal heat balance to establish the corresponding outlet temperatures of the three flow streams, namely hot water GH, cooling water GC, and chilled water GE. The calculation sequence for this part is first outlined as follows:

- (1) Input GH, GC, GE, TH1, TA1, TE1 and an off-design tonnage, (see fig. 1).
- (2) Calculate flow rate per ton for flow GH, GC, and GE.
- (3) Calculate effectiveness (eq. (2)) for exchanger G, C, A, and E.
- (4) Calculate TE2, TE, TH2, and TG.
- (5) Calculate TC2 with an assumed COP.
- (6) Assume TA.
- (7) Calculate TC.
- (8) If TA or TC exceed limits, change tonnage.
- (9) Calculate TG, TC, TA, and TE with newly assumed tonnage.
- (10) Calculate solution concentration.
- (11) If X1 or X4 exceeds limits, change tonnage.
- (12) Calculate enthalpies H8 and H10 of refrigerant at outlets of condenser C and evaporator E, respectively.
- (13) Calculate refrigerant flow GR and solution flows GS and GW, respectively.
- (14) Calculate effectiveness EFFNX of solution exchanger.
- (15) Calculate two outlet temperatures T3 and T5 of solution exchanger.
- (16) Calculate refrigerant enthalpy H7 at outlet of generator G, weak solution enthalpy H5 at outlet of solution exchanger X, and strong solution enthalpy H, at outlet of absorber A.
- (17) Calculate generator heat QG, condenser heat QC, and absorber heat QA.
- (18) Calculate COP.
- (19) If TA is not agreeable with assumed value, adjust TA to suit.
- (20) If COP is not agreeable with assumed value, adjust COP to suit.
- (21) Check temperature difference limits.
- (22) Check pumping rate limits.
- (23) Check concentration limits.
- (24) Force tonnage to maximum.

(25) Check chilled water outlet temperature TE2 at set point.

(26) Calculate pressure PE and PC.

To establish the reference conditions, several of the aforementioned indicated steps are repeated. The algorithm used depends upon the information available.

If all the design or reference temperatures are given but the flow rates are not, steps (10) to (18) and step (26) are repeated. The flow rates and all reference (UA)'s are the calculated outputs. The effectiveness of the solution heat exchanger can be calculated from the known temperatures (eq. (12) as an input to the program).

If all three external flow rates are known instead of their outlet temperatures, steps (1) to (18) and step (26) are repeated. In this case the corresponding outlet temperatures are determined.

If the outlet temperature of the solution heat exchanger T5 or its effectiveness is not given, an assumed effectiveness must be used as an input until a rated reference tonnage is found.

PROGRAM DESCRIPTION

The computer program was written in FORTRAN IV language. It can be used as a subroutine to simulate the absorption machine performance in a cooling system. Although the equations derived are steady-state type, no restriction is imposed for use in the transient analysis of a cooling system.

When used as a subroutine, the program may have to be modified to accept a set of the design or the test conditions. The flow rates and the inlet and outlet temperatures of the three external fluid streams are system connected to run the simulation. If additional outputs such as heat loads, COP, and operating pressures are required, they may be system linked or printed out for analysis.

When used as an independent program, the first case is treated as the reference case. The program calculates additionally needed reference values and stores these values automatically in the program. Starting with the next case, the user inputs as many off-design cases as are desired. NAMELIST input is used in the program.

All tolerances for the limitation conditions discussed previously have been prestored in the program but can be changed as desired. The units system used to perform the calculation is metric but provision to use British units for inputs and outputs is included. Changing either the units or the tolerances shall be discussed in the next section and appendix B.

OPERATION OF THE PROGRAM

Use as a Subroutine

If the program is used as a subroutine, the reference data and program controls must be inserted as data statements or their equivalent by the user. The required data are UAG0, UAC0, UAE0, UAA0, UAX0, GS0, GW0, and TON0. The controls are FQG, METRIC, KLBHR, and JWRITE (see appendixes B and C).

The input variables are currently placed in an array called XIN. These variables (listed in order), are GHT, GCT, GET, TH1, GA1, TE1, and TONX (see appendixes B and C).

The output variables are arranged in an array OUT. These variables are GHT, GCT, GET, TH2, TC2, TE2, and TON. If additional outputs such as COP, PC, and PE are required, the user may place these variables in the additional locations of array OUT (see appendixes B and C).

Use as the Main Program

If the program is used independently, the reference data must be calculated from this program based upon the available design or experimental informations. The input variables in this case will be TH2, TA2, or TC2, TE2, TH1, TA1, TE1, TG, TC, TA, TE, TON0, TONX, KLBHR, METRIC, and JREF (see appendix B and fig. 1). TONX is the initial guess of the actual load. The data are entered via a NAMELIST read and are for reference case. The NAMELIST name is REF. The first tabulated output will be the results of the design conditions and the table is identified with a case marked 0.

To run other cases with fixed heat-transfer surfaces (the same machine), additional cases are placed in the run stream with a NAMELIST name of VAR. As many cases as desired can be run. The input for these cases are GH, CC, GE, TH1, TA1, TE1, and TONX (see appendixes B and C). The outputs are tabulated as before, and the case is identified with a case number greater than 0.

The convergence is controlled by KTA, KCOP, KTON1, and KTON2. If the number of the iterations is excessive, the output may be incorrect. The user must examine the results to decide whether he should increase the number of iterations, or discontinue his run because of exceeding machine operating constraints.

The tolerance controls for the temperatures and concentrations are currently pre-stored in the program (see appendixes B and C). The values may be changed to suit the user's purpose.

SAMPLE CALCULATIONS

Two sample computer printouts are included to demonstrate the use of the program in appendix C.

Sample 1 shows that, for a given set of the design conditions, the program not only finds the correct design load but generates the results for the off-design loads as well.

The absorption machine used in the sample calculations is a TRANE model C1H (ref. 6). This model was designed for a nominal rated tonnage at 174 tons. The print-out table (case 0) shows that the calculated tonnages agree with the design load. The output of this case is then stored in the program as the reference data of the machine to be used for the off-design runs.

A total of 130 off-design cases (the off-design loads and operating conditions in table 2C1H of ref. 6), have been run with the program. Most of the calculated tonnages agree with the data in reference 6 within 2 percent and generally are slightly greater than the table values (two typical cases are shown in appendix C). In some of the cases, however, the calculated values are high by 9 percent. These cases usually are associated with the extremely high or low outlet temperature of the chilled water. All cases were run on the assumption that the nominal design flow rates were chosen to establish the rated table values. If these flow rates are not nominal but varied within the design range, the program calculated tonnages can be brought to agreement with those tables indicated.

Sample 2 was intended to show that, with minor changes, the program can be used as a subroutine in a system program. In this case the system program is TRNSYS (ref. 1). Sample 2 is a solar assisted building cooling system modeled with TRNSYS program (see appendix C).

CONCLUDING REMARKS

A computer model of a LiBr-H₂O single-stage absorption machine has been developed. By utilizing a given set of design data but without knowing the interior characteristics of the machine, the off-design performance can be simulated or evaluated. Although the model is not validated experimentally, it can be a useful tool for analyzing the capability of a given machine, or for studying the machine performance in a cooling system.

Lewis Research Center,

National Aeronautics and Space Administration,

Cleveland, Ohio, May 16, 1978,

776-22.

APPENDIX A

SYMBOL LIST, THERMODYNAMIC FORMULAS, AND EQUATIONS FROM REFERENCE 1

Strong concentration ($X_1 > 0.5$):

$$X_1 = \frac{(49.04 + 1.125 T_A - T_E)}{(134.65 + 0.47 T_A)} \quad \frac{\text{kg LiBr}}{\text{kg solution}}$$

Weak concentration ($X_4 < 0.65$):

$$X_4 = \frac{(49.04 + 1.125 T_G - T_C)}{(134.65 + 0.47 T_G)} \quad \frac{\text{kg LiBr}}{\text{kg solution}}$$

Enthalpy of condenser outlet:

$$H_8 = (T_C - 25) \quad \text{kcal/kg}$$

Enthalpy of evaporator outlet:

$$H_{10} = (572.8 + 0.417 T_E) \quad \text{kcal/kg}$$

Refrigerant flow:

$$GR = \frac{Q_E}{(H_{10} - H_8)} \quad \frac{\text{kg}}{\text{hr}}$$

Strong solution flow:

$$GS = GR \frac{X_4}{(X_4 - X_1)} \quad \frac{\text{kg}}{\text{hr}}$$

Weak solution flow:

$$GN = GR \frac{X_1}{(X_4 - X_1)} \quad \frac{\text{kg}}{\text{hr}}$$

Heat capacity of strong solution:

$$CX1 = 1.01 - 1.23(X1) + 0.48(X1)^2 \quad \text{kcal/(kg)}(^{\circ}\text{C})$$

Heat capacity of weak solution:

$$CX4 = 1.01 - 1.23(X4) + 0.48(X4)^2 \quad \text{kcal/(kg)}(^{\circ}\text{C})$$

Outlet temperature of weak solution

$$T5 = TG - (EFFNX)(TG - TA) \quad ^{\circ}\text{C}$$

Outlet temperature of strong solution:

$$T3 = TA + (EFFNX) \left(\frac{X1}{X4} \right) \left(\frac{CX4}{CX1} \right) (TG - TA) \quad ^{\circ}\text{C}$$

Enthalpy of absorber outlet:

$$H1 = [42.81 - 425.92(X1) + 404.67(X1)^2] + [1.01 - 1.23(X1) + 0.48(X1)^2](TA) \quad \text{kcal/kg}$$

Enthalpy of weak solution at heat exchanger outlet:

$$H5 = [42.81 - 425.92(X4) + 404.67(X4)^2] + [1.01 - 1.23(X4) + 0.48(X4)^2](T5) \quad \text{kcal/kg}$$

Enthalpy of refrigerant at generator outlet:

$$H7 = (572.8 + 0.46 TG - 0.043 TC) \quad \text{kcal/kg}$$

Condenser heat load:

$$QC = (GR)(H7 - H8) \quad \text{kcal/hr}$$

Generator heat load:

$$QG = (GW)(H5) + (GR)(H7) - (GS)(H1) \quad \text{kcal/hr}$$

Absorber heat load:

$$QA = (GW)(H5) + (GR)(H10) - (GS)(H1) \quad \text{kcal/hr}$$

Coefficient of performance:

$$COP = \frac{QE}{QG}$$

Evaporator heat load:

$$QE = 3024.0 \quad \text{kcal/hr}$$

Evaporator pressure:

$$PE = \text{antilog}_{10} \left(7.8553 - \frac{1555}{TE + 273.15} - \frac{11.2414 \times 10^4}{(TE + 273.15)^2} \right) \quad \text{mm Hg}$$

Condenser pressure:

$$PC = \text{antilog}_{10} \left(7.8553 - \frac{1555}{TC + 273.15} - \frac{11.2414 \times 10^4}{(TC + 273.15)^2} \right) \quad \text{mm Hg}$$

APPENDIX B

SYMBOL LIST FOR HEAT-TRANSFER CALCULATIONS IN COMPUTER PROGRAM

Flow rates, gal/min, lb/hr, kg/hr

| | |
|----|---------------------------|
| GH | (Hot water supply) |
| GC | (Cooling water supply) |
| GA | (Cooling Water supply) |
| GE | (Returning chilled water) |
| GR | (Refrigerant - water) |
| GW | (Weak solution) |
| GS | (Strong solution) |

Temperatures, °F, °C

| | |
|-------------------|-------------------------------------|
| TH1, TH2 | (Inlet and outlet conditions of GH) |
| TC1, TC12, or TA2 | (Inlet and outlet conditions of GA) |
| TC12, TC2 | (Inlet and outlet conditions of GC) |
| TE1, TE2 | (Inlet and outlet conditions of GE) |
| TG | (Generator) |
| TC | (Condenser) |
| TA | (Absorber) |
| TE | (Evaporator) |

Heat-transfer rates, Btu/(hr)(°F), cal/(hr)(°C)

| | |
|--------------|-----------------------------------|
| UAG | (Generator) |
| UAC | (Condenser) |
| UAA | (Absorber) |
| UAE | (Evaporator) |
| UAX | (Heat exchanger) |
| First digit | Overall heat-transfer coefficient |
| Second digit | Overall heat-transfer surface |
| Third digit | Component symbol |

Number of heat-transfer units

| | |
|------|------------------|
| NTUG | (Generator) |
| NTUC | (Condenser) |
| NTUA | (Absorber) |
| NTUE | (Evaporator) |
| NTUX | (Heat exchanger) |

Heat-transfer effectiveness

| | |
|-------|------------------|
| EFFNG | (Generator) |
| EFFNC | (Condenser) |
| EFFNA | (Absorber) |
| EFFNE | (Evaporator) |
| EFFNX | (Heat exchanger) |

(A digit 0 following aforementioned symbols signifies a reference or a design condition being used. A digit T following aforementioned symbols and symbols in appendix A signifies total quantities.)

| | |
|--------|---|
| TON0 | (Reference refrigerant tonnage) |
| TON | (Tonnage calculated) |
| TONX | (Tonnage variable) |
| COPX | (COP variable) |
| TAX | (TA variable) |
| GSC1 | (Product of strong solution flow and heat capacity) |
| GWC4 | (Product of weak solution flow and heat capacity) |
| CRATIO | =GWC4/GSC4 |
| EXPX | (Exponential function for heat exchanger) |

Controls and limits

| | |
|--------|--------------------------------|
| METRIC | (Input to be metric units > 0) |
| KLBHR | (Input to be lb/hr > 0) |
| JWRITE | (Write output > 0) |
| KTA | (TA converging cycle = 50) |
| KCOP | (COP converging cycle = 50) |

| | |
|-------------------------------|------------------------------------|
| KTON1 and KTON2 | (TONX converging cycle = 100) |
| ACONST = 1.0 ⁰ C | Limits of (TE2 - TE) |
| BCONST = 1.296 ⁰ C | Limits of (TA - TC12) |
| CCONST = 1.425 ⁰ C | Limits of (TC - TC2) |
| DCONST = 1.919 ⁰ C | Limits of (TH1 - TG) |
| TELO = 2.22 ⁰ C | (Lowest temperature limits of TE) |
| TE2SET = 4.43 ⁰ C | (Lowest temperature limits of TE2) |
| COPHI = 0.93 | (Highest limits of COP) |
| COPLO = 0.60 | (Lowest limits of COP) |
| FQG = 1.0 | (No heat loss added) |
| EFFNX = 0.71428 | (Initialization of EFFNX) |

APPENDIX C

SAMPLES 1 AND 2 WITH PROGRAM LISTINGS

Sample 1: LiBr-H₂O Single-Stage Absorption Machine Used as a Main Program

```

10  C   USE THIS TO EVALUATE OUTPUT OF AN ABSORPTION MACHINE WITH FIXED --UA--
20  C   ALL WATER SPECIFIC HEAT & DENSITY ASSUMED TO BE --1.0-- EXCEPT HOT WATER
30  C   DIMENSION XIN( 0),PAR(10),XNTU(6),EFFN(6)
40  C   DIMENSION X(6),Y(6),GIN(3)
50  C   DIMENSION TONGVN(160),TONCAL(160)
60  C
70  C--METRIC=0, BRITISH UNITS USED.-----JWRITE=1 WRITE ALL,JWRITE=0 NO WRITE
80  C   KLBHR=0,GPM FOR FLOW INPUT.-----KLBHR=1, LBS/HR INPUT
90  C   DATA METRIC/0/,KLBHR/0/,JWRITE/1/
100 C   DATA PWK/7.4536/
110 C   DATA TFC1/32./,TFC2/1.8/
120 C   DATA CALBTU/3.06831/
130 C
140 C
150 C   CONST1 & CONST4 ARE CONCENTRATION LIMITS
160 C   DATA CONST1/0.47,CONST4/0.68/
170 C   A-B-C-D-CONST ARE LIMITS FOR EVAP., ABSORP., COND., & GENERATOR
180 C   DATA ACONST/1./,BCONST/1.296/,CCONST/1.423/,DCONST/1.919/
190 C
200 C   DATA TELO/2.22/,TE2SET/4.43/
210 C   COP LIMITS      ---HEAT LOSS FACTOR
220 C   DATA COPHI/0.93/,COPLO/0.66/,FQG/1.0/
230 C   EFFNX=0.71426   FOR TS=135 F      EFFNX=(TG-TS)/(TG-TA)
240 C   DATA EFFNX/0.71426/
250 C
260 C   DIMENSION XINRSV(10)
270 C   DIMENSION AJTE2(4)
280 C   DATA      AJTE2(1),AJTE2(2),AJTE2(3),AJTE2(4) / 3MTH1 , 3MTE1 ,
290 C   1 3MTH2 , 3MTE2 /
300 C   DIMENSION AJREF(2)
310 C   DATA AJREF(1),AJREF(2)/ 3MTC2 , 3MTA2 /
320 C   DATA JTE2 / 0 /
330 C   DTLM=0.25
340 C   DTLM=0.1
350 C   NAMELIST /REF/ TH2,TA2,TC2,TE2,TH1,TA1,TE1,TG,TC,TA,TE,TONL,
360 C   1 KLBHR,METRIC,JREF,CONST1,CONST4,ACONST,BCONST,CCONST,DCONST,
370 C   2 COPHI,COPLO,FQG,EFFNX,TELO,TE2SET
380 C   NAMELIST /VAR/ GH,GC,GE,TH1,TA1,TE1,TONX,JTE2,TE2,TH2,LVAP
390 C
400 C   JREF=0,RUN NO REF.  -JREF=1,TC2=XIN(2).--JREF=2,TA2 OR TC12=XIN(2)
410 C   300 READ(5,REF)
420 C   LVAR=0
430 C   XIN(1)=TH2
440 C   IF(JREF.EQ.1) XIN(2)=TC2
450 C   IF(JREF.EQ.2) XIN(2)=TA2
460 C   XIN(3)=TE2
470 C   XIN(4)=TH1
480 C   XIN(5)=TA1
490 C   TC1=TA1
500 C   XIN(6)=TE1
510 C   XIN(7)=TG
520 C   XIN(8)=TC
530 C   XIN(9)=TA
540 C   XIN(10)=TE
550 C   DO 302 I=1,10
560 C   XINRSV(I)=XIN(I)
570 C   302 CONTINUE
580 C   TC2RSV=TC2
590 C   TA2RSV=TA2
600 C   4ERRDP=0
610 C
620 C
630 C

```

```

64*      IFIMETRIC.GT.1)  TFTC1=0.0
65*      IFIMETRIC.GT.0)  TFTC2=1.0
66*      IFIMETRIC.GT.C)  PDKG=1.0
67*      IFIMETRIC.GT.0)  CALBTU=1.0
68*      IFIMETRIC.GT.C)  BPM=1.0
69*      C
70*      BPM=500.0
71*      IF(KLPHR.GT.0)  BPM=1.0
72*      C
73*      IF(JREF.GT.0)  GO TO 19
74*      7 CONTINUE
75*      C  -----UA VALUES ARE PER TON BASIS-----
76*      TOND=TON
77*      GSD=GS*PDKG
78*      GWD=GW*PDKG
79*      GHD=GHT
80*      GED=GET
81*      GCD=GCT
82*      PAR(1)=UAG*PDKG
83*      PAR(2)=UAC*PDKG
84*      PAR(3)=UAF*PDKG
85*      PAR(4)=UAA*PDKG
86*      PAR(5)=UAX*PDKG
87*      UAXD=PAR(5)
88*      C
89*      C
90*      INPUT=1
91*      C
92*      990 CONTINUE
93*      JREF=0
94*      READ(5,VAR,END=999)
95*      XIN(1)=GH
96*      XIN(2)=GC
97*      XIN(3)=GE
98*      XIN(4)=TH1
99*      XIN(5)=TA1
100*      TC1=TA1
101*      XIN(6)=TL1
102*      XIN(7)=TONX
103*      GESAV=XIN(3)
104*      TE2SAV=TE2
105*      TH2SAV=TH2
106*      KERROR=0
107*      C  TON IS AN ASSUMED VALUE TO START
108*      TONX=XIN(7)
109*      TONREF=TOND*0.5
110*      TONMIN=TOND*0.1
111*      TONMAX=TOND*1.2
112*      IF(XIN(7).LE.TONREF)  TONX=TONREF
113*      C
114*      19 CONTINUE
115*      C
116*      KGC=0
117*      9 CONTINUE
118*      C
119*      C  -----FLOW RATES ARE PER TON BASIS -----
120*      C  PER TON BASIS
121*      QE=3023.9573
122*      H1=0.
123*      H5=0.
124*      H7=0.
125*      H8=0.
126*      H10=0.
127*      TON=J.0
128*      KTON1=0
129*      KTON2=0
130*      KTONX=-1

```

```

131*      X=C.67
132*      XI=C.41
133*      I=RTF=0
134*      11 CONTINUE
135*      C      COPX=C.722
136*      IF(COPX.LF.COPLO.OR.COPX.GE.COPHI)  COPX=C.722
137*      *COP=0
138*      16 CONTINUE
139*          GH=XIN(11)/TONX*PDHG*BPW*3.975
140*          GC=XIN(12)/TONX*PDHG*BPW
141*          GE=XIN(13)/TONX*PDHG*BPW
142*          TH1=XIN(41)-TFTC11/TFTC2
143*          TC1=XIN(151)-TFTC11/TFTC2
144*          TE1=XIN(161)-TFTC11/TFTC2
145*          T2SVW=1T2SAV-TFTC11/TFTC2
146*          TH2SVW=1TH2SAV-TFTC11/TFTC2
147*      C
148*          IF(IJHF.EQ.0)  GO TO 20
149*          TH2=XIN(11)-TFTC11/TFTC2
150*          TA2=XIN(121)-TFTC11/TFTC2
151*          IF(IJHF.EQ.2)  TC12=TA2
152*          IF(IJHF.EQ.1)  TC2=TA2
153*          TE2=XIN(131)-TFTC11/TFTC2
154*          TS=XIN(171)-TFTC11/TFTC2
155*          TC=XIN(181)-TFTC11/TFTC2
156*          TA=XIN(191)-TFTC11/TFTC2
157*          TE=XIN(101)-TFTC11/TFTC2
158*          GO TO 21
159*      20 CONTINUE
160*      C      ASSUME TUBE SIDE WATER FILM COEF. IS CONTROLLING
161*          GH1=XIN(11)/GHD1**0.8
162*          GC1=XIN(121)/GCD1**0.8
163*          GE1=XIN(131)/GED1**0.8
164*      C
165*      C      TOTAL RASTS    IN METRIC UNITS
166*          SIN11=GM/GH1*TONX
167*          GIN121=GC/GC1*TONX
168*          SIN131=GE/GE1*TONX
169*      C
170*          DO 13 I=1,4
171*          XNTU11=PAR111/GIN111*1.0*TONF
172*          IF(1.FD.4)  XNTU11=PAR111/GIN121*TONF
173*          IF(XNTU111.GE.1F.1)  GO TO 8
174*          EFFN111=1.F-EXP(-XNTU111)
175*          GO TO 14
176*      * CONTINUE
177*          EFFN111=0.999
178*      10 CONTINUE
179*      C
180*      C
181*          TE2=TE1-WF/GE
182*          TH2=TH1-1GE/COPX1/GH
183*      C
184*      C      FOR CHECKING TRANE TABLE FIGURES ONLY      TE2 *TH2 KNOWN INSTEAD
185*          IF(IJF2.LF.6)  GO TO 602
186*          TE2=TE1
187*          TH2=TH1
188*      C      TE2=TF2SAV
189*      C      TH2=TH2SAV
190*          TE2=TF2SVW
191*          TH2=TH2SVW
192*          TE1=TF2*GF/GE
193*          TH1=TH2*1GE/COPX1/GH
194*      602 CONTINUE
195*      C
196*      C
197*          TE=TE1-(TF1-TE2)/EFFN131

```

```

1980      TG=TH1-(TH1-TH2)/EFFN11
1990      TC2=TC1+11.0+1.0/COPX1*OE/EC
2000      C      ASSUMED A VALUE FOR TA
2010      TA2=(TC1+TC2)*0.5
2020      TA=TC1-(TC1-TA2)/EFFN14
2030      KTA=0
2040      15 CONTINUE
2050      TC=TC2/EFFN121-11.0/EFFN121-1.01+1TC1+EFFN141+1TA-TC111
2060      IF(TE.LF.TA) GO TO 40
2070      IF(TE.GE.TA) GO TO 41
2080      IF(TE.GT.TG) GO TO 41
2090      C
2100      21 CONTINUE
2110      X1=(49.04+1.125*TA-TE)/(1134.65+3.47*TA)
2120      X4=(49.04+1.125*TG-TC)/(1134.65+3.47*TG)
2130      IF(X1.LT.CONST1) GO TO 45
2140      IF(X4.LF.X1) GO TO 43
2150      C
2160      H6=TC-25.0
2170      H10=572.8+0.417*TE
2180      GR=GE/1H10-H6
2190      SS=GR*XX/(XX-X1)
2200      GW=GS*(X1/X4)
2210      C
2220      CX1=1.01-1.23*X1+0.48*X1**2
2230      CX4=1.01-1.23*X4+0.48*X4**2
2240      GSC1=GS*CX1
2250      GWC4=GW*CX4
2260      CRATIO=GWC4/GSC1
2270      IF(JREF.GT.0) GO TO 27
2280      C
2290      C      ASSUMING ORIGINAL FILM COEF. EQUAL ON BOTH SIDES.--GW ON SWELL SIDE
2300      F1=2.0
2310      F2=1.0
2320      C      F1=2,F2=1,HG5=HGW.--F1=1,F2=0,HG5>>HGW.--F1=2.5,F2=2/3,HG5=1.5HGW. FOR UAX
2330      RG5=(165/G5)*(TOND/TONX)**0.8
2340      RGW=(165/GW)*(TOND/TONX)**0.6
2350      UAX=F1*UAXD+11.0/(RG5+F2*RGW)
2360      C
2370      IF(GWC4.GT.GSC1) GO TO 17
2380      XNTUX=UAX/GWC4*(TOND/TONX)
2390      GO TO 18
2400      C
2410      17 CONTINUE
2420      XNTUX=UAX/GSC1*(TOND/TONX)
2430      CRATIO=GSC1/GWC4
2440      18 CONTINUE
2450      C
2460      IF(ABS(1.-CRATIO).LT.0.01) GO TO 12
2470      IF(XNTUX+1.-CRATIO).GE.10.) GO TO 12
2480      EAPX=(XPI-XNTUX+1.0-CRATIO)
2490      EFFNX=(1.0-(EAPX)/(1.0-CRATIO)*EAPX)
2500      GO TO 14
2510      C
2520      12 CONTINUE
2530      EFFNX=0.999
2540      GO TO 14
2550      13 CONTINUE
2560      EFFNX=XNTUX/11.0*XNTUX
2570      14 CONTINUE
2580      22 CONTINUE
2590      C
2600      C
2610      T5=TG-(EFFNX*(TG-TA))
2620      T3=TA+(EFFNX*CRATIO*(TG-TA))
2630      C
2640      H1=(42.61-425.97*X1+424.67*X1**2)*CX1+T8

```

```

265*      H5=(42.81-425.97*X4+404.67*X4**2)+CX4*TS
266*      H7=572.8+C.46*TG-D.043*TC
267*
268*      C      FQG=1.D,NO HEAT LOSS.--FQG>1.D,&K2.D,& HEAT LOSS
269*      IF(FQG.LE.1.D) FQG=1.D
270*      QC=(GW*H5-GS*H1+GR*H7)*FQG
271*      QC=GR*(H7-H8)*(1.D+QG/(QG+QE))*(1.D-FQG)
272*      QA=(GW*H5-GS*H1+GR*H1D)*(1.D+QG/(QG+QE))*(1.D-FQG)
273*      COP=QE/QG
274*
275*      C      IF(JREF.GT.0) GO TO 60
276*
277*      C      TC12=TC1+QA/GC
278*      TAX=TC1-(TC1-TC12)/EFFN(4)
279*
280*      C
281*      40 CONTINUE
282*      IF(TC.LE.TA) TAX=TC
283*      IF(ABS(TAX-TA).LT.D.DDDC1) GO TO 41
284*      IF(KTA.EQ.50) GO TO 41
285*      TA=(TAX+TA)*0.5
286*      KTA=KTA+1
287*      GO TO 15
288*
289*      C      41 CONTINUE
290*      IF(ABS(COPX-COP).LT.D.DDDC1) GO TO 42
291*      IF(KCOP.EQ.50) GO TO 42
292*      COPX=(COPX+COP)*0.5
293*      KCOP=KCOP+1
294*      GO TO 16
295*
296*      C      42 CONTINUE
297*      X(1)=TE2-TE
298*      X(2)=TA-TC12
299*      X(3)=TC-TC2
300*      X(4)=TH2-TG
301*      Y(1)=ACONST
302*      Y(2)=BCONST
303*      Y(3)=CCONST
304*      Y(4)=DCONST
305*
306*      C
307*      DO 47 I=1,4
308*      IF(X(I).LT.Y(I).AND.KTONX.EQ.1) GO TO 60
309*      IF(X(I).LT.Y(I)) GO TO 45
310*
311*      C      47 CONTINUE
312*      IF(X1.GT.CONST1.AND.X4.LT.CONST4.AND.X4.GT.X1) GO TO 46
313*
314*      C
315*      45 CONTINUE
316*      IF(KTON2-100) 49,43,43
317*
318*      C      49 CONTINUE
319*      TONMIN=TONX
320*      TONX=(TONX+TONMAX)*0.5
321*      ITONX=IFIX(TONX)
322*      TONX=TONX + DTLIM
323*      KTON2=KTON2+1
324*      GO TO 11
325*
326*      C
327*      43 CONTINUE
328*      IF(KTON1-100) 44,65,65
329*
330*      C      44 CONTINUE
331*      TONMAX=TONX
332*      TONX=(TONX+TONMIN)*0.5
333*      ITONX=IFIX(TONX)
334*      IF(TON.LE.D.O.AND.TONX.LE.(TONMIN+1.C)) GO TO 60
335*      IF(TONX.LE.TON) GO TO 50
336*      TONX=FLCAT(ITONX)-1.D
337*      TONX=TONX - DTLIM

```

```

332*      KTON1=KTON1+1
333*      GO TO 11
334*  C
335*      46 CONTINUE
336*      IF(KTONX.EQ.1.OR.TONX.LE.0.D) GO TO 60
337*      IF(TON.GE.TONX) GO TO 50
338*  C      CHECK MAX. STRONG SOLUTION PUMP RATE -----
339*      GSTC=GSP*TONC
340*      GSPUMP=GS*TONX
341*      IF(GSPUMP.GT.GSTC) GO TO 43
342*  C
343*      TON=TONX
344*      IF(TE2.LT.TE2SETL.OR.TE.LE.TELC) GO TO 48
345*      GO TO 49
346*      48 CONTINUE
347*      TON=TON*(TE1-TE2SET)/(TE1-TE2)
348*  C
349*      50 CONTINUE
350*      IF(KTONX.EQ.1.OR.TON.LE.0.D) GO TO 60
351*      TONX=TON
352*      KTONX=1
353*      GO TO 11
354*  C
355*      60 CONTINUE
356*      65 IF(JREF.GT.0.OR.KTONX.EQ.1.OR.KGC.GE.0) GO TO 66
357*      KGC=KGC+1
358*      XIN(3)=XIN(3)*(TONX-1.D)/TONX
359*      GO TO 9
360*      66 CONTINUE
361*  C
362*  C
363*  C-----ALL SPEC HEAT = 1. -----
364*      IF(JREF.EQ.0) GO TO 35
365*      TON=TONC
366*      YY=(1.-EFFNX*CRATIO)/(1.-EFFNX)
367*      XNTUX=ALOG(YY)/(1.-CRATIO)
368*      GH=QG/(TH1-TH2)
369*      GE=QE/(TE1-TE2)
370*      IF(JREF.EQ.1) GC=(QA+QC)/(TC2-TC1)
371*      IF(JREF.EQ.2) GC=QA/(TC12-TC1)
372*      IF(JREF.EQ.1) TC12=TC1+QA/GC
373*      IF(JREF.EQ.2) TC2=TC12+QC/GC
374*      EFFN(1)=(TH1-TH2)/(TH1-TG)
375*      EFFN(2)=(TC12-TC2)/(TC12-TC)
376*      EFFN(3)=(TE1-TE2)/(TE1-TE)
377*      EFFN(4)=(TC1-TC12)/(TC1-TA)
378*      DO 31 K=1,4
379*      XNTU(K)=(-1.)*ALOG(1.-EFFN(K))
380*      31 CONTINUE
381*  C
382*      35 CONTINUE
383*      UAG=XNTU(1)*GH
384*      UAC=XNTU(2)*GC
385*      UAE=XNTU(3)*GE
386*      UAA=XNTU(4)*GC
387*      UAX=XNTUX*GWC4
388*  C
389*      A=ALOG(10.D)
390*      B=1555.D/(TE+273.15)
391*      C=11.2414F4/(TE+273.15)**2
392*      PE=EXP(A*(17.8553-B-C))
393*      P=1555.D/(TC+273.15)
394*      C=11.2414F4/(TC+273.15)**2
395*      PC=EXP(A*(17.8553-B-C))
396*  C
397*      QG=QG*CALPTU
398*      QC=QC*CALPTU

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```

3990      QE=QE*CALRTU
4000      QA=QA*CALRTU
4010      H1=H1*CALRTU
4020      H5=H5*CALRTU
4030      H7=H7*CALRTU
4040      H8=H8*CALRTU
4050      H10=H10*CALRTU
4060      C
4070      T3=T3*TFTC2*TFTC1
4080      T5=T5*TFTC2*TFTC1
4090      C
4100      TH1=TH1*TFTC2*TFTC1
4110      TH2=TH2*TFTC2*TFTC1
4120      TC1=TC1*TFTC2*TFTC1
4130      TC12=TC12*TFTC2*TFTC1
4140      TA2=TC12
4150      TC2=TC2*TFTC2*TFTC1
4160      TE1=TE1*TFTC2*TFTC1
4170      TE2=TE2*TFTC2*TFTC1
4180      TE =TE *TFTC2*TFTC1
4190      TA =TA *TFTC2*TFTC1
4200      TC =TC *TFTC2*TFTC1
4210      TG =TG *TFTC2*TFTC1
4220      C
4230      UAG=UAG/PDKG
4240      UAC=UAC/PDKG
4250      UAE=UAE/PDKG
4260      UAA=UAA/PDKG
4270      UAX=UAX/PDKG
4280      GH=GH/PDKG
4290      GC=GC/PDKG
4300      GA=GC
4310      GE=GE/PDKG
4320      GR=GR/PDKG
4330      GW=GW/PDKG
4340      GS=GS/PDKG
4350      GSC1=GSC1/PDKG
4360      GWC4=GWC4/PDKG
4370      C
4380      QGT=QG*TON
4390      QCT=QC*TON
4400      QET=TON
4410      QAT=QA*TON
4420      UAGT=UAG*TON
4430      UACT=UAC*TON
4440      UAET=UAE*TON
4450      UAAT=UAA*TON
4460      GHT=GH*TON/BPH/7.975
4470      SCT=GC*TON/BPH
4480      GAT=GCT
4490      GET=GF*TON/BPH
4500      DT12E=TE1-TE2
4510      DT12A=TA2-TC1
4520      DT12C=TC2-TA2
4530      DT12G=TH1-TH2
4540      DTE2=TE2-TE
4550      DTA2=TA-TA2
4560      DTC2=TC-TC2
4570      DTG2=TH2-TG
4580      C
4590      IF(KTA.GE.50.OR.KCOP.GE.50) GO TO 58
4600      IF(KTON2.GE.100.OR.KTON1.GE.100) GO TO 58
4610      IF(JWRITE.EQ.0) GO TO 59
4620      GO TO 430
4630      EF CONTINUE
4640      KLRPOP=1
4650      C

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```

466# IF(METRIC.GT.0) WRITE(6,420)
467# FORMAT(1H1,2DX,'OUTPUT IS IN SI UNITS DEGREES C, KG/HR, CAL * / )
468# IF(METRIC.EQ.0) WRITE(6,421)
469# 421 FORMAT(1H1,2DX,'OUTPUT IS IN U.S. CUSTOMARY UNITS - DEGREES F, GPM
470# 1, BTU * / )
471# IF(ERROR.EQ.1) WRITE(6,431)
472# 431 FORMAT(///2DX,'***** ITERATIONS FAILED TO CONVERGE *****
473# 100 * )
474# IF(METRIC.EQ.0 .AND. INPUT.EQ.0) WRITE(6,93) AJREF(JREF)
475# IF(METRIC.GT.0 .AND. INPUT.EQ.0) WRITE(6,193) AJREF(JREF)
476# IF(INPUT.EQ.0) WRITE(6,94) (XIN(I),I=1,10),TONC,JREF,INPUT
477# IF(INPUT.EQ.0) GO TO 57
478# JOUT=1
479# IF(JTE2.GT.0) JOUT=3
480# IF(METRIC.GT.0) WRITE(6,195) AJTE2(JOUT),AJTE2(JOUT+1)
481# IF(METRIC.EQ.0) WRITE(6,95) AJTE2(JOUT),AJTE2(JOUT+1)
482# IF(JTE2.EQ.0)
483# 1WRITE(6,98) KTA,KCOP,KTON2,KTON1,(XIN(I),I=1,6),TONX,XIN(7),INPUT
484# IF(JTE2.GT.0) WRITE(6,98) KTA,KCOP,KTON2,KTON1,XIN(1),XIN(2),
485# 1 XIN(3),TH2SAV,XIN(5),TF2SAV,TONX,XIN(7),INPUT
486# 57 CONTINUE
487#
488# C
489# WRITE(6,403)
490# WRITE(6,402) X1,X4,CX1,CX4,GH,GS,GW,GSC1,GWC4,EXPX,CRTATIO,UAX
491# WRITE(6,407)
492# WRITE(6,402) TA,T5,T3,TG,H1,H5,H7,H8,H10,XNTUX,EFFNX,COP
493# WRITE(6,406)
494# WRITE(6,405) GE,TE1 ,TE2,TE ,XNTU(3),EFFN(3),PE,UAE,QE,GET,UAE
495# XT,GET
496# WRITE(6,404) GA,TC1 ,TA2,TA ,XNTU(4),EFFN(4),PE,UAA,QA,GAT,UAA
497# XT,QAT
498# WRITE(6,401) GC,TA2,TC2,TC ,XNTU(2),EFFN(2),PC,UAC,OC,GCT,UACT,Q
499# XCT
500# WRITE(6,400) GH,TH1 ,TH2,TG ,XNTU(1),EFFN(1),PC,UAG,QG,GHT,UAG
501# XT,OGT
502# 400 FORMAT(1X,4HG---,7F10.3,5E10.3//)
503# 401 FORMAT(1X,4HC---,7F10.3,5E10.3//)
504# 402 FORMAT(1X,4HX---,12F10.3//)
505# 403 FORMAT(5X,12GH X1 X4 CX1 CX4 GF
506# X GS GW GSC1 GWC4 EXPX CRTATIO UAX
507# X )
508# 404 FORMAT(1X,4HA---,7F10.3,5E10.3//)
509# 405 FORMAT(1X,4HE---,7F10.3,5E10.3//)
510# 406 FORMAT(5X,12GH G T1 T2 T NTU
511# X EFFN P UA Q GT UAT OT
512# X )
513# 407 FORMAT(5X,12GH TA T5 T3 TG H1
514# X H5 H7 H8 H10 NTUX EFFNX COP
515# X )
516# C
517# WRITE(6,96)
518# WRITE(6,97) DT12L,DTE2,TE2,DT12A,DTA2,TA2,DT12C,DTC2,TC2,DT12G,DTG
519# X2,TH2
520# 93 FORMAT(10X,'TH2-F',5X,A3,'-F',5X,'TE2-F',5X,'TH1-F',5X,'TC1-F',
521# 1 5X,'TE1-F',5X,'TG-F',6X,'TC-F',6X,'TA-F',6X,'TE-F',4X,'TON-REF',
522# 2 5X,'JREF',5X,'NO,' )
523# 193 FORMAT(10X,'TH2-C',5X,A3,'-C',5X,'TE2-C',5X,'TH1-C',5X,'TC1-C',
524# 1 5X,'TE1-C',5X,'TG-C',6X,'TC-C',6X,'TA-C',6X,'TE-C',4X,'TON-REF',
525# 2 5X,'JREF',5X,'NO,' )
526# 94 FORMAT(5X,11F10.3,11D,3X,I3//)
527# 95 FORMAT(10X,'KTA KCOP KTON2 KTON1 GHT-GPM GCT-GP
528# 1H GHT-GPM',5X,A3,'-F TC1-F',5X,A3,'-F TON-CAL TON-START
529# 2 NO,' )
530# 195 FORMAT(10X,'KTA KCOP KTON2 KTON1 GHT-KPH GCT-KP
531# 1H GHT-KPH',5X,A3,'-C TC1-C',5X,A3,'-C TON-CAL TON-START
532# 2 NO,' )
533# 96 FORMAT(1X,12GH DT12L DTE2 TE2 DT12A DTA2

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5330      X  TA2      DT12C      DTC2      TC2      DT12G      DTG2      TH2
5340      X      )
5350      97 FORMAT(1X,4HTEMP,12F10.3///)
5360      98 FORMAT(5X,4(I6,2X),8F10.3,3X,I3/)
5370      C
5380      59 CONTINUE
5390      IF(JREF.GT.0)      GO TO 7
5400      C
5410      41 CONTINUE
5420      C
5430      TONGVN(INPUT)=XIN(7)
5440      TONCAL(INPUT)=TON
5450      INPUT=1+INPUT
5460      SH=XIN(1)
5470      SC=XIN(2)
5480      GE=GESAV
5490      TH1=XIN(4)
5500      TA1=XIN(5)
5510      TE1=XIN(6)
5520      TONX=XIN(7)
5530      TE2=TF2SAV
5540      TH2=TH2SAV
5550      IF(LVAR.EQ.0) GO TO 990
5560      DO 301 I=1,10
5570      XINRSV(I)=XIN(I)
5580      301 CONTINUE
5590      TC2=TC2RSV
5600      TA2=TA2RSV
5610      GO TO 300
5620      999 CONTINUE
5630      WRITE(6,601)
5640      C      WRITE(6,602) (TONGVN(M),TONCAL(M),M=1,160)
5650      WRITE(6,602) (M,TONGVN(M),TONCAL(M),M=1,160)
5660      601 FORMAT(1X,110HTHE FOLLOWING ARE KNOWN TON VS CALCULATED FOR TRANE
5670      1 MODEL C1H/DS-APS1      TH2,TE2,TC1 ARE KNOWN      )
5680      C 602 FORMAT(1X,6(4X,2F8.2)/ / (1X,6(4X,2F8.2)/)
5690      602 FORMAT(1X,6(I4,2F8.2)/ / (1X,6(I4,2F8.2)/)
5700      C
5710      STOP
5720      END

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[illegible]

| | HT | WCP | WON2 | WON1 | GMT-OPN | GET-OPN | GET-OPN | YMI-F | YCI-F | YFI-F | YON-CAL | YON-STADY | CSO |
|------|----------|---------|---------|---------|----------|----------|----------|---------|----------|--------|---------|-----------|-----|
| | 10 | 11 | 0 | 0 | 150.272 | 551.000 | 417.470 | 273.470 | 80.000 | 50.420 | 141.912 | 141.000 | 1 |
| A--- | 81 | 84 | 81 | 84 | 60 | 65 | 64 | 65 | 64 | 64 | 64 | 64 | |
| | 158 | 151 | 151 | 151 | 11.976 | 123.773 | 111.794 | 56.745 | 56.147 | 56.147 | 56.147 | 56.147 | |
| A--- | TA | TS | T7 | T6 | H1 | H7 | H7 | H8 | H10 | H10 | L708 | L778 | |
| | 107.341 | 120.187 | 146.378 | 279.344 | -200.573 | -141.476 | 2445.731 | 67.912 | 7276.574 | 2.241 | 775 | 774 | |
| E--- | 0 | T1 | T7 | T | H10 | L778 | P | U1 | 0 | 0 | L77 | 0 | |
| | 1147.871 | 50.420 | 70.974 | 75.702 | 1.273 | 774 | 5.276 | 1.444 | 1.276 | 1.187 | 1.187 | 1.187 | |
| A--- | 1520.246 | 80.000 | 80.177 | 100.341 | 602 | 449 | 5.276 | 104.74 | 154.75 | 553.71 | 193.46 | 291.47 | |
| C--- | 1523.246 | 90.157 | 98.456 | 107.804 | 607 | 442 | 61.979 | 999.71 | 120.75 | 553.03 | 182.76 | 275.77 | |
| G--- | 072.002 | 273.470 | 270.770 | 279.344 | 1.444 | 666 | 61.979 | 641.71 | 1.444 | 157.71 | 162.75 | 200.77 | |
| TEMP | PT12E | PT12E | PT1 | PT12A | DTA2 | T42 | PT12C | DTA2 | PT12C | PT12C | PT12C | PT12C | |
| | 10.434 | 4.182 | 30.974 | 16.157 | 10.184 | 90.157 | 8.449 | 9.149 | 98.656 | 40.491 | 17.415 | 220.770 | |

[illegible]

Sample 2: LiBr-H₂O Single-Stage Absorption Machine Used as a Subroutine in TRNSYS

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10      SUBROUTINE TYPE17(TIME,XIN,OUT,T,DTDT,PAR)
20      COMMON /PR2/ TIME,T,TFINAL,DELT
30      C   USE THIS TO EVALUATE OUTPUT OF AN ABSORPTION MACHINE WITH FIXED --UA--
40      C   ALL WATER SPECIFIC HEAT & DENSITY ASSUMED TO BE --1.C-- EXCEPT HOT WATER
50      DIMENSION PAR(10),XIN(10),OUT(10)
60      DIMENSION X(6),Y(6),CIN(3),XNTU(6),EFFN(6),PER(6)
70      C
80      C--METRIC=0,BRITISH UNITS USED.-----JWRITE=1 WRITE ALL,JWRITE=0 NO WRITE
90      C   KLRHR=0,GPM FOR FLOW INPUT.----KLRHR=1, LBS/HR INPUT
100     DATA METRIC/0/,KLRHR/1/,JWRITE/1/
110     DATA METRIC/0/,KLRHR/1/,JWRITE/0/
120     DATA PDWG/.4536/
130     DATA TFC1/32./,TFC2/1.8/
140     DATA CALRTU/3.96931/
150     C
160     C   CONST1 & CONST4 ARE CONCENTRATION LIMITS
170     DATA CONST1/0.4/,CONST4/0.68/
180     C   A-R-C-D-CONST ARE LIMITS FOR EVAP., ABSORP., COND.,& GENERATOR
190     DATA ACONST/1./,BCONST/1.296/,CCONST/1.423/,DCONST/1.919/
200     DATA TELO/2.22/,TE2SET/4.43/
210     C   COP LIMITS --HEAT LOSS FACTOR
220     DATA COPHI/0.93/,COPLO/0.66/,FQG/1.0/
230     C   EFFNX=0.71428 FOR TS=135 F EFFNX=(TG-TS)/(TG-TA)
240     DATA EFFNX/0.71428/
250     C
260     C
270     C
280     C
290     INPUT=1
300     990 CONTINUE
310     H1=0.
320     H5=0.
330     H7=0.
340     H8=0.
350     H10=0.
360     C
370     C   -----UA VALUES ARE PER TON BASIS-----
380     UAG=456.981*PDWG
390     UAC=1011.869*PDWG
400     UAE=1503.294*PDWG
410     UAA=1102.8*PDWG
420     UAX=116.929*PDWG
430     UAXQ=118.929*PDWG
440     GSD=144.077*PDWG
450     CWL=131.323*PDWG
460     GHD=150.786*500.*0.975
470     GEQ=417.600 *500.
480     GCG=543.674*500.
490     TONE=174.
500     C
510     C
520     C
530     C
540     PER(1)=UAG
550     PER(2)=UAC
560     PER(3)=UAE
570     PER(4)=UAA
580     PER(5)=UAX
590     C
600     JREY=1
610     7 CONTINUE
620     TONX=XIN(7)/12000.
630     TONREF=TONX*0.5
640     TONPINT=TONX*0.1
650     TONPAY=TONX*0.12

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66* C
67* C KLRHR=0.0PM GPM INPUT.--KLRHR=1.3PM INPUT FOR FLOW RATE
68* RPH=50.0
69* IF(KLRHR.GT.0) RPH=1.0
70* C
71* 9 CONTINUE
72* C
73* C -----FLOW RATES ARE PER TON BASIS -----
74* C PER TON BASIS
75* TON=1.0
76* KTON1=0
77* KTON2=0
78* KTONX=-1
79* X4=0.67
80* X1=0.41
81* C 5 --IS A CONTROL COST.--S=0. OUT=INLET--S=1 OUT CALCULATED
82* S=1.0
83* 11 CONTINUE
84* CS=CS*
85* KCOF=1
86* 16 CONTINUE
87* IF(COPX.LE.COPLO.OR.COPX.GE.COPHI) COPX=C.722
88* C
89* C
90* GH=XIN(1)/TONX*PDKG*RPH*0.975
91* GC=XIN(2)/TONX*PDKG*RPH
92* GE=XIN(3)/TONX*PDKG*5PM
93* TH=(XIN(4)-TFTC1)/TFTC2
94* TC1=(XIN(5)-TFTC1)/TFTC2
95* TE1=(XIN(6)-TFTC1)/TFTC2
96* QF=3023.9573
97* TC12=TC1
98* TG=TH
99* TA=TC1
100* TC=TC1
101* TE=TE1
102* T2=TA
103* T5=T6
104* DO 6 I=1,7
105* IF(XIN(I).LE.0.0001) S=0.0
106* 6 CONTINUE
107* IF(S.LE.0.0001) GO TO 5
108* C
109* C ASSUME TUBE SIDE WATER FILM COEF. IS CONTROLLING
110* GH1=(XIN(1)/GHL)**0.8
111* GC1=(XIN(2)/GCL)**0.8
112* GE1=(XIN(3)/GEL)**0.8
113* C
114* C TOTAL BASIS IN METRIC UNITS
115* GIN(1)=GH/GH1*TONX
116* GIN(2)=GC/GC1*TONX
117* GIN(3)=GE/GE1*TONX
118* C
119* DO 10 I=1,4
120* IF(GIN(I).LE.0.0) GO TO 8
121* XNTU(I)=PRR(I)/GIN(I)*1.0*TONC
122* IF(1.E0.4) XNTU(I)=PRR(I)/GIN(2)*TONC
123* IF(XNTU(I).GE.10.) GO TO 8
124* EFFN(I)=1.0-EXP(-XNTU(I))
125* GO TO 10
126* 8 CONTINUE
127* EFFN(1)=0.999
128* 10 CONTINUE
129* C
130* C
131* 5 CONTINUE
132* IF(TIME.LE.TIME7.OR.TE1.LE.TE2SET) TE1=TE2SET

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133*      IF (T1.LT.TE25C1) 5=7.0
134*      TE2=TE1-QE/GE*5
135*      TH2=TH1-(QE/COPX)/GH*5
136*      TC=TE1+11.0+1.0/COPX*QE/GE*5
137*      IF (5.LT.7.7001) GO TO 20
138*
139*      C
140*      TF=TE1-(TE1-TE2)/EFFN(1)
141*      TC=TH1-(TH1-TH2)/EFFN(1)
142*      C
143*      ASSUMED A VALUE FOR TA
144*      TA2=(TC1+TC2)*0.5
145*      TA=TC1-(TC1-TA2)/EFFN(4)
146*      *TA=
147*
148*      15 CONTINUE
149*      C
150*      IF (TA.LT.(TC1+1.0)) GO TO 43
151*      TC=TC2/EFFN(2)-(1.0/EFFN(2)-1.0)*(TC1-EFFN(4)*(TA-TC1))
152*
153*      C
154*      IF (TC.LT.TA) GO TO 41
155*      IF (TE.GE.TA) GO TO 41
156*      IF (TC.GE.TG) GO TO 41
157*
158*      C
159*      X1=(49.04+1.125*TA-TF)/(134.65+0.47*TA)
160*      X4=(49.04+1.125*TG-TC)/(134.65+0.47*TG)
161*      IF (X1.LT.CONST1) GO TO 45
162*      IF (X4.LT.X1) GO TO 43
163*
164*      C
165*      HR=TC-25.0
166*      HIC=572.8+0.417*TF
167*      GR=QE/(HIC-HR)
168*      GS=GR*X4/(X4-X1)
169*      GW=GS*(X1/X4)
170*
171*      C
172*      CX1=1.01-1.23*X1+0.48*X1**2
173*      CX4=1.01-1.23*X4+0.48*X4**2
174*      GSC1=GS*CX1
175*      GWC4=GW*CX4
176*      CRATIO=GWC4/GSC1
177*
178*      C
179*      ASSUMING ORIGINAL FILM COEF. EQUAL ON BOTH SIDES.--GW ON SHELL SIDE
180*      F1=2.0
181*      F2=1.0
182*
183*      C
184*      F1=2,F2=1,HGS=HGW.--F1=1,F2=0,HGS>>HGW.--F1=2.5,F2=2/3,HGS=1.5HGW. FOR UAX
185*      RES=(165./GS)*(TOND/TONX)**0.8
186*      RGW=(1650/GW)*(TOND/TONX)**0.6
187*      UAX=F1*UAXD*(1.0/(165.*F2*RGW))
188*
189*      C
190*      IF (GWC4.GT.GSC1) GO TO 17
191*      XNTUX=UAX/GWC4*(TOND/TONX)
192*      GO TO 19
193*
194*      C
195*      17 CONTINUE
196*      XNTUX=UAX/GSC1*(TOND/TONX)
197*      CRATIO=GSC1/GWC4
198*
199*      18 CONTINUE
200*      C
201*      IF (ABS(1.0-CRATIO).LT.0.01) GO TO 13
202*      IF ((XNTUX*(1.-CRATIO)).GE.17.0) GO TO 12
203*      EXPX=EXP(1-XNTUX*(1.-CRATIO))
204*      EFFNX=11.0-EXPX/(1.-CRATIO*EXPX)
205*      GO TO 14
206*
207*      C
208*      12 CONTINUE
209*      EFFNX=1.999
210*      GO TO 14
211*
212*      13 CONTINUE
213*      EFFNX=XNTUX/(1.0-XNTUX)
214*
215*      14 CONTINUE

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200* C
201* C
202* T5=TG-EFFNX*(TG-TA)
203* T7=TA+L*FFNX*(KAT10*(TG-TA))
204* C
205* H1=(47.81-425.92*X1+404.67*X1**2)*CX1*TA
206* H5=(47.81-425.92*X4+414.67*X4**2)*CX4*TS
207* H7=577.8+0.46*TG-0.043*TC
208* C
209* C FQG=1.0,NO HEAT LOSS.--FQG>1.0,LC2.0,3 HEAT LOSS
210* IF(FQG.LE.1.0) FQG=1.0
211* QG=(GW*HS-GS*H1)*G0*H7)*FQG
212* QE=GR*(H7-HR1)*(1.7*QG/(QG+QF))*(1.0-FQG)
213* QF=(GW*HS-GS*H1)*G0*H17)*(1.7*QG/(QG+QE))*(1.0-FQG)
214* COP=QF/QG
215* C
216* TC12=TC1*QA/GC
217* IF(TC12.GE.TC2) TC12=TC1+1.0
218* TAX=TC1-(TC1-TC12)/FFN(4)
219* C
220* 40 CONTINUE
221* IF(TC.LE.TA) TAX=TC
222* IF(ABS(TAX-TA).LT.0.0001) GO TO 41
223* IF(MTA.EQ.57) GO TO 41
224* TA=(TAX+TA)*0.5
225* MTA=MTA+1
226* GO TO 15
227* 41 CONTINUE
228* C
229* IF(ABS(COPX-COP).LT.0.0001) GO TO 42
230* IF(MCOP.EQ.50) GO TO 42
231* COPX=(COPX+COP)*0.5
232* MCOP=MCOP+1
233* GO TO 16
234* 42 CONTINUE
235* C
236* X(1)=TC2-TF
237* X(2)=TA-TC12
238* X(3)=TC-TC2
239* X(4)=TH2-TG
240* Y(1)=ACONST
241* Y(2)=PCONST
242* Y(3)=CCONST
243* Y(4)=DCONST
244* C
245* DO 47 I=1,4
246* IF(X(I).LT.Y(I)).AND.MTONX.EQ.1) GO TO 61
247* IF(X(I).LT.Y(I)) GO TO 45
248* 47 CONTINUE
249* C
250* IF(X1.GT.CONST1.AND.X4.LT.CONST4.AND.X4.GT.X1) GO TO 46
251* C
252* 45 CONTINUE
253* IF(KTON2-100) 44,43,43
254* 49 CONTINUE
255* TONMIN=TONX
256* TONX=(TONX+TONMAX)*0.5
257* ITONX=FIX(TONX)
258* TONX=FLOAT(ITONX)+1.0
259* KTON2=KTON2+1
260* GO TO 11
261* C
262* 43 CONTINUE
263* IF(KTON1-100) 44,50,50
264* 44 CONTINUE
265* TONMAX=TONX
266* TONX=(TONX+TONMIN)*0.5

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267*      ITONX=IFIX(ITONX)
268*      IF(TON.LE.1.D.AND.TONX.LE.(TONMIN+1.D)) GO TO 50
269*      IF(TONX.LE.TON)      GO TO 50
270*      TONX=FLOAT(ITONX)-1.D
271*      KTON1=KTON1+1
272*      GO TO 11
273*
274*      C
275*      46 CONTINUE
276*      IF(KTONX.EQ.1.OR.TONX.LE.0)      GO TO 60
277*      IF(TON.GE.TONX) GO TO 50
278*      C CHECK MAX. STRONG SOLUTION PUMP RATE -----
279*      GSTC=65.D*TONC
280*      GSPUMP=GS*TONX
281*      IF(GSPUMP.GT.GSTC) GO TO 43
282*      C
283*      TON=TONX
284*      IF(TE2.LT.TE2SET.OR.TE.LE.TE1) GO TO 46
285*      GO TO 49
286*      48 CONTINUE
287*      TON=TON*(TE1-TE2SET)/(TE1-TE2)
288*      C
289*      50 CONTINUE
290*      IF(KTONX.EQ.1)      GO TO 60
291*      TONX=TON
292*      IF(TON.LE.1.D) S=0.D
293*      KTONX=1
294*      GO TO 11
295*      C
296*      60 CONTINUE
297*      C
298*      C-----ALL SPEC HEAT = 1. -----
299*      UAG=XNTU(1)*GH
300*      UAC=XNTU(2)*GC
301*      UAE=XNTU(3)*GE
302*      UAA=XNTU(4)*GC
303*      C
304*      A=ALOG(13.D)
305*      B=1555.D/(TF+273.15)
306*      C=11.2414E4/(TE+273.15)**2
307*      PC=EXP(A*(7.8553-B-C))
308*      R=1555.D/(TC+273.15)
309*      C=11.2414E4/(TC+273.15)**2
310*      PC=EXP(A*(7.8553-B-C))
311*      C
312*      80 CONTINUE
313*      QC=QG*CALBTU
314*      GC=GC*CALBTU
315*      QE=GE*CALBTU
316*      QF=QA*CALBTU
317*      H1=H1*CALBTU
318*      H5=H5*CALBTU
319*      H7=H7*CALBTU
320*      H8=H8*CALBTU
321*      H12=H12*CALBTU
322*      C
323*      T1=T3+TF*TC2+TF*TC1
324*      T5=T5+TF*TC2+TF*TC1
325*      C
326*      TH1=TH1+TF*TC2+TF*TC1
327*      TH2=TH2+TF*TC2+TF*TC1
328*      TC1=TC1+TF*TC2+TF*TC1
329*      TC12=TC12+TF*TC2+TF*TC1
330*      T12=TC12
331*      TC2=TC2+TF*TC2+TF*TC1
332*      TF1=TF1+TF*TC2+TF*TC1
333*      TF2=TF2+TF*TC2+TF*TC1

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334*      TL =TF *TFTC2+TFTC1
335*      TA =TA *TFTC2+TFTC1
336*      TC =TC *TFTC2+TFTC1
337*      TG =TG *TFTC2+TFTC1
338*      C
339*      UAG=UAG/PDKG
340*      UAC=UAC/PDKG
341*      UAE=UAE/PDKG
342*      UAA=UAA/PDKG
343*      UAX=UAX/PDKG
344*      GH=GH/PDKG
345*      GC=GC/PDKG
346*      GP=GC
347*      GF=GE/PDKG
348*      GR=GR/PDKG*5
349*      GW=GW/PDKG*5
350*      GS=GS/PDKG*5
351*      GSC1=GSC1/PDKG*5
352*      GWC4=GWC4/PDKG*5
353*      C
354*      QCT=QG*TON*5
355*      QCT=QC*TON*5
356*      QET=TON
357*      QAT=QA*TON*5
358*      UAGT=UAG*TON
359*      UACT=UAC*TON
360*      UAET=UAE*TON
361*      UAAT=UAA*TON
362*      GHT=GH*TON/RPH/0.975
363*      GCT=GC*TON/RPH
364*      GAT=GCT
365*      GET=GE*TON/RPH
366*      DT17E=TF1-TF2
367*      DT12A=TA2-TC1
368*      DT12C=TC2-TA2
369*      DT12G=TH1-TH2
370*      DTE2=TE2-TE
371*      DTA2=TA-TA2
372*      DTC2=TC-TC2
373*      DTG2=TH2-TG
374*      C
375*      C
376*      IF(JWRITE.EQ.0) GO TO 59
377*      IF(AMOD(TIME,1.000).GT.DELT) GO TO 500
378*      WRITE(6,95)
379*      TONXIN=XIN(7)
380*      XIN(7)=TONXIN/12000.
381*      WRITE(6,98) KTA,KCOP,KTON?,KTON1,(XIN(I),I=1,6),TONX,XIN(7),INPUT
382*      XIN(7)=TONXIN
383*      WRITE(6,403)
384*      WRITE(6,402) X1,X4,CX1,CX4,GR,GS,GW,GSC1,GWC4,EXPX,CRATIO,UAX
385*      WRITE(6,407)
386*      WRITE(6,402) TA,TF,T3,TG,H1,H5,H7,H9,H10,XNTUX,EFFNX,COP
387*      WRITE(6,406)
388*      WRITE(6,405) GL,TF1 ,TE?,TE ,XNTU(3),EFFN(3),PE,UAE,QE,GET,UAE
389*      XT,QFI
390*      WRITE(6,404) GA,TC1 ,TA2,TA ,XNTU(4),EFFN(4),PE,UAA,QA,GAT,UAA
391*      XT,QAT
392*      WRITE(6,401) GC,TA2,TC2,TC ,XNTU(2),EFFN(2),PC,UAC,QC,GCT,UACT,Q
393*      XCT
394*      WRITE(6,400) GH,TH1 ,TH2,TG ,XNTU(1),EFFN(1),PC,UAG,GS,GHT,UAG
395*      XT,QGT
396*      400 FORMAT(1X,4H0---,7F10.3,5E10.3//)
397*      401 FORMAT(1X,4H0---,7F10.3,5E10.3//)
398*      402 FORMAT(1X,4HX---,12F10.3//)
399*      403 FORMAT(5X,12DH X1 X4 CX1 CX4 GR GS GW GSC1 GWC4 EXPX CRATIO UAX
400*      X GS GW GSC1 GWC4 EXPX CRATIO UAX

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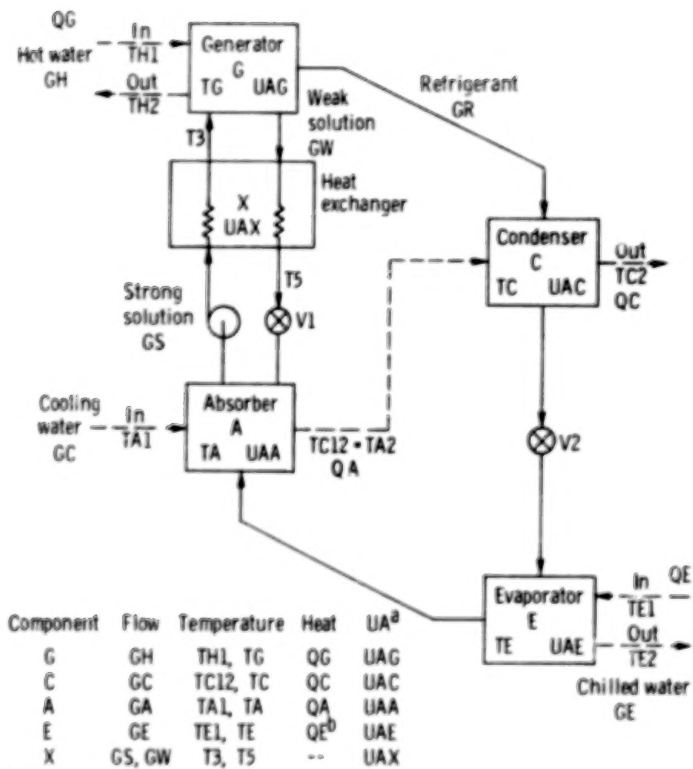
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4010      X      1
4020      404 FORMAT(1X,4HA---,7F10.3,5E10.3/)
4030      405 FORMAT(1X,4HE---,7F10.3,5E10.3/)
4040      406 FORMAT(5X,12CH      5      T1      T2      T      NTU
4050      X      EFFN      P      UA      0      GT      UAT      DT
4060      X      1
4070      407 FORMAT(5X,12CH      TA      TS      T3      T6      H1
4080      X      H5      H7      H8      H10      NTUX      EFFNX      COP
4090      X      1
4100      C
4110      WRITE(6,96)
4120      WRITE(6,97) DT12E,DTL2,TE2,DT12A,DTA2,TA2,DT12C,DTC2,TC2,DT12G,DTG
4130      X2,TH2
4140      95 FORMAT(5X,12CH      KTA      KCOP      KTON2      KTON1      SHT-GPM
4150      X      GET-GPM      GET-GPM      TH1-F      TC1-F      TE1-F      TON-CAL      TON-ST
4160      XAPT      NO. 1
4170      96 FORMAT(5X,12CH      DT12E      DTE2      TE2      DT12A      DTA2
4180      X      TA2      DT12C      DTC2      TC2      DT12G      DTG2      TH2
4190      X      1
4200      97 FORMAT(1X,4HTEMP,12F10.3///)
4210      98 FORMAT(5X,4I18,2X),AF10.3,3X,13/)
4220      99 FORMAT(7F10.1)
4230      C
4240      59 CONTINUE
4250      573 CONTINUE
4260      OUT(1)=TH2
4270      OUT(2)=XIN(1)
4280      OUT(3)=TON*DE
4290      OUT(4)=TH2
4300      OUT(5)=DGT
4310      OUT(6)=TE2
4320      OUT(7)=XIN(3)
4330      OUT(8)=TC2
4340      OUT(9)=XIN(3)
4350      OUT(10)=TON*DE
4360      C
4370      INPUT=1+INPUT
4380      RETURN
4390      C      STOP
4400      END

```

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^aUA = Product of overall heat-transfer coefficient and its surface area.

^bQE = 1 TON; QET = Total (not shown with total flows, heats, and UA's).

Figure 1. - Flow diagram of single-stage LiBr-H₂O absorption unit.

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| 16 Abstract <p>A computer model of a LiBr-H₂O single-stage absorption machine has been developed. The model, utilizing a given set of design data such as water-flow rates and inlet or outlet temperatures of these flow rates but without knowing the interior characteristics of the machine (heat transfer rates and surface areas), can be used to predict or simulate off-design performance. Results from 130 off-design cases for a given commercial machine agree with the published data within 2 percent.</p> | | | |
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